TRIBOELECTROSTATIC SEPARATION OF UNBURNED CARBON FROM FLY ASH

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ABSTRACT

Due to differences in the surface physical and chemical properties of the carbon and ash, particles of unburned carbon and fly ash can be electrically charged to opposite polarity, and can be separated by passing them through an external electric field. A laboratory scale triboelectrostatic separation system was used to study fly ash beneficiation. Fly ash samples, characterized by size analysis and carbon content, were subjected to triboelectrostatic separation. The separated fractions were collected and evaluated for carbon content, and subjected to SEM. The results indicate the potential for applying dry separation technology for removing unburned carbon from coal ash.

INTRODUCTION

Fly ash from pulverized coal power plants is a marketable commodity, provided acceptable levels of carbon are maintained.[1] With the advent of low NO_x burners, the carbon content in fly ash in many cases has increased to the point where it is no longer marketable and becomes a disposal liability. Dry triboelectrostatic separation technology is just beginning to be applied to recover purified ash from fly ash streams which contain high concentrations of carbon.[2] Due to differences in the surface physical and chemical properties of the carbon and ash, they can be electrically charged to opposite polarity by particle-to-particle or by particle-to-surface contact. By manipulating the polarity and magnitude of this charge, the carbon and ash can be separated by passing them through an external electric field, see Figure 1. The successful application of dry separation technology to ash purification would be significant because it would eliminate water handling and treatment problems associated with wet beneficiation methods.

Dry electrostatic separation technology has been utilized in the mineral processing industry and most recently has been considered for coal beneficiation.[3-7] The US DOE has funded several projects focusing on both the fundamentals and development of dry coal beneficiation technologies based on electrostatics.[8] As a consequence of these efforts, a greater understanding of factors relating to the particle charging and electrostatic separation has been achieved. While the cost of processing is a major factor in the economic feasibility of coal beneficiation, it is not as important in the case of fly ash beneficiation. Economic factors of equal or higher importance include the avoided cost of ash disposal and the market value of the processed ash. Depending on geographic location, it is possible that the application of efficient dry ash separation technologies could be very beneficial to coal utilization systems.

Very little has been published on the application of dry triboelectrostatic separation to fly ash beneficiation. There is a need for optimizing dry fly ash separation technologies because of the vast amount of coal ash produced in the US and the growing interest in applying superior technologies with respect to their economical and environmental performance. In this paper, results from the triboelectrostatic separation of two coal fly ashes are presented. These experiments were conducted at a laboratory scale. The design of the triboelectrostatic separation system and the data obtained on the ashes in this study will be used in future work to optimize ash separation using feed rates typical to industrial and utility systems.

EXPERIMENTAL

A laboratory scale triboelectrostatic separation system, shown in Figure 2, was used in the fly ash benificiation study. The fly ash was metered by using a vibratory feeder, contained in a sealed environment tank, into a pneumatic transport tube where it was entrained in a N_2 carrier gas. The gas-particle mixture was then passed through a tribocharging unit where the fly ash was charged by particle-particle or particle-wall frictional contact. The exit of the charger was connected to a separation chamber which contained parallel copper plates across which was established a high intensity electric field. A filter was placed at the bottom of the separation chamber to catch any entrained fly ash particles. The exit of the separation chamber was connected to an induced draft fan.

About 10 grams of ash sample were weighed and used for each separation test. The average carrier gas flow velocity was about 15 m/s. The electric field strength was maintained at 200 kV/m.

The fly ash samples were acquired from either ESP hoppers or storage silos at two pulverized coal boilers. Prior to separation tests, the samples were evaluated for particle size and carbon content.

After the triboelectrostatic separation, samples were collected from predetermined locations throughout the separation chamber, and their weight and carbon content determined. Representative sample fractions were also prepared and examined using scanning electron microscopy (SEM) and energy dispersive spectrometry (EDS).

RESULTS AND DISCUSSIONS

During separator operation, fractions of carbon and ash were deposited on the electrodes. For both electrodes, the depositions appeared to be long narrow ribbons of material, starting from near the exit of the transporting tube and extending to the end of the copper plates. Analysis of sequential axial sections of the depositions showed the carbon content to be highest at the top of the negative electrode and lowest at the top of the positive electrode. The carbon content on the positive electrode increased with distance while that on the negative electrode decreased with distance. In other words, the ash was the purest at the top of the positive plate and the carbon the purest at the top of the negative plate. Since the carbon and ash content on the electrodes could be represented by a continuous distribution, it was possible to make an arbitrary split of the separated products that satisfied desired purity requirements. However, as in any physical separation processes, higher purity products are achieved at the expense of lower yield.

A procedure was established for separated sample collection and analysis. For each test, there were a total of ten sample fractions collected; eight from four axial regions of the two electrodes, one from the center filter, and one removed from the vertical plexiglass windows. These fractions along with the feed were weighed and analyzed for their carbon content. An eleventh data point, which represents the material which was not captured anywhere in the separator, was determined by performing a mass and carbon balance. The separation results were plotted in a manner similar to a washability or release analysis curve, using the analogy of each fraction being either a float or sink product. These data include an assessment of mass balances. A second stage separation could be performed by putting the fraction collected on the center filter back to the feeder, and process the data with those from the first stage separation.

Carbon and ash recovery, and particle size and carbon distributions, for the fly ash sample A are shown in Figure 3-5. This sample was obtained from a utility boiler burning bituminous coal having an intermediate sulfur content. Over 65% of the ash was recovered with a carbon content of less than 3%, while about 50% of the carbon in the ash was recovered with a carbon content greater than 35%. The particle size distribution data show that there is a significant amount of the ash with sizes greater than 150 μm and with sizes below 25 mm. This wide distribution of particle size presents a significant challenge to dry separation systems due to an order of magnitude range in aerodynamic drag and gravitational forces. For this particular ash, the carbon concentrations for each size fraction are in a descending order, as shown in Figure 3, from the highest in the largest size fraction to the lowest in the smallest size fraction.

Separation results for fly ash sample B are presented in Figure 6-7. This sample was obtained from a utility burning intermediate-to-high sulfur coal. The ash recovery data is plotted for a one stage and a two stage processing scheme. The application of the second stage increased the ash recovery by about 15% and, hence, may be important to the overall processing scheme. These data show that nearly 55% of the ash was recovered with a carbon content of less than 3% while over 60% of the carbon could be recovered with a carbon purity greater than 40%. These results suggest the utility of dry ash separation. Important chemical and physical properties of the fly ashes which affect or control efficient dry ash separation are currently under investigation.

CONCLUSIONS

This study has shown that dry triboelectrostatic separation of fly ash has the potential to be an effective method of separating unburned carbon from fly ash. Laboratory tests on a simple parallel flow separator showed that 60-80% of ash could be recovered at carbon contents below 5%, and 50% of carbon could be recovered at carbon concentrations over 50%. Additional studies should be initiated to evaluate the effects of ash properties on separation with the goal of optimizing the beneficiation process.

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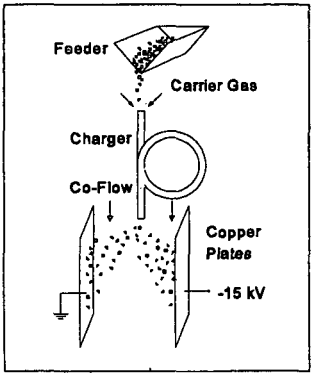

Figure 1: Electrostatic separation principle

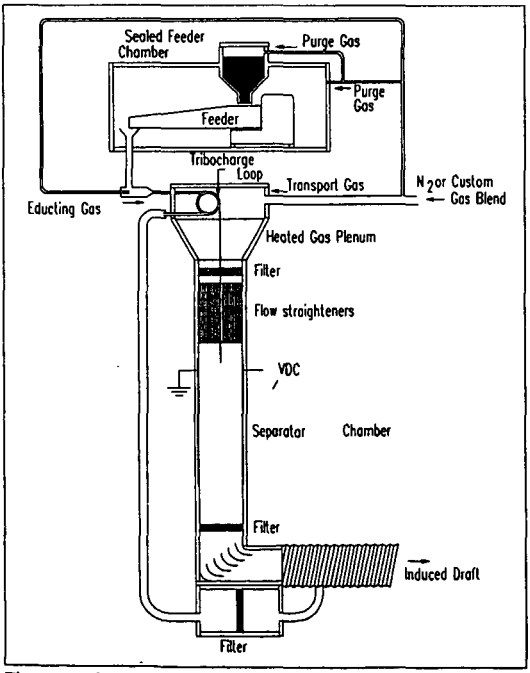

Figure 2: The schematic of the test system.

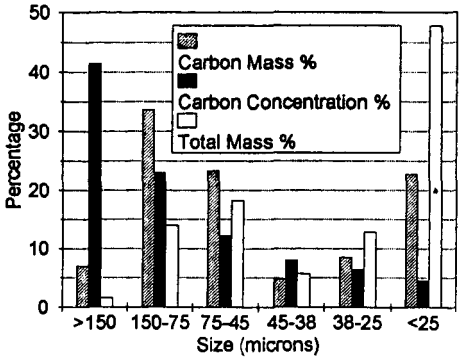

Figure 3: Percentage fly ash weight, carbon concentration, and carbon mass distributions in each size fractions for fly ash sample A.

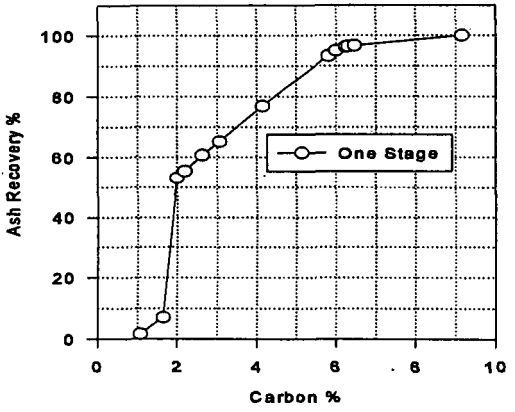

Figure 4: Ash recovery curve for sample A.

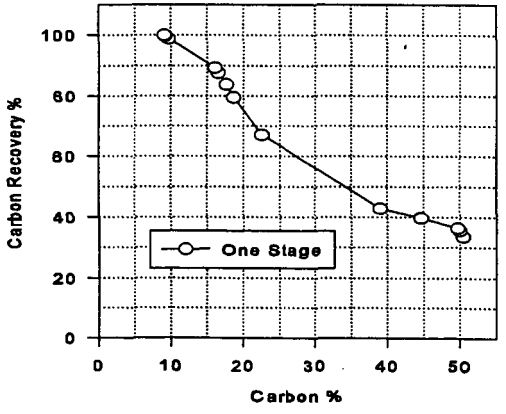

Figure 5: Carbon recovery curve for sample A.

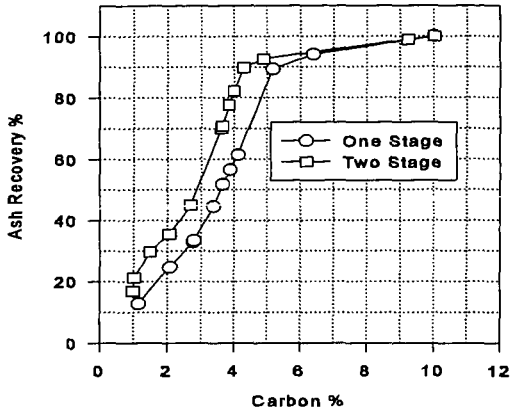

Figure 6: Ash recovery curve for sample B.

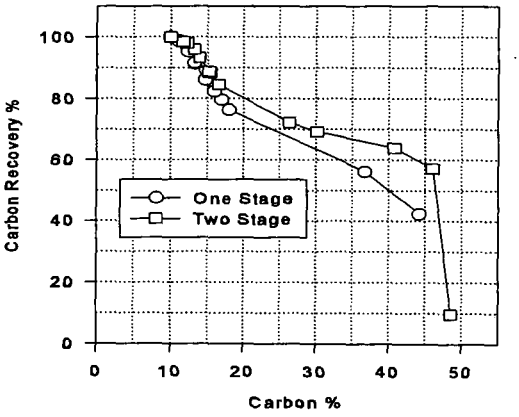

Figure 7: Carbon recovery curve for sample B.